Jan. 15, 1957 H. L. McNEILL 2,777,577

ORE CONCENTRATION AND APPARATUS THEREFOR

Filed March 12, 1951 2 Sheets-Sheet 1

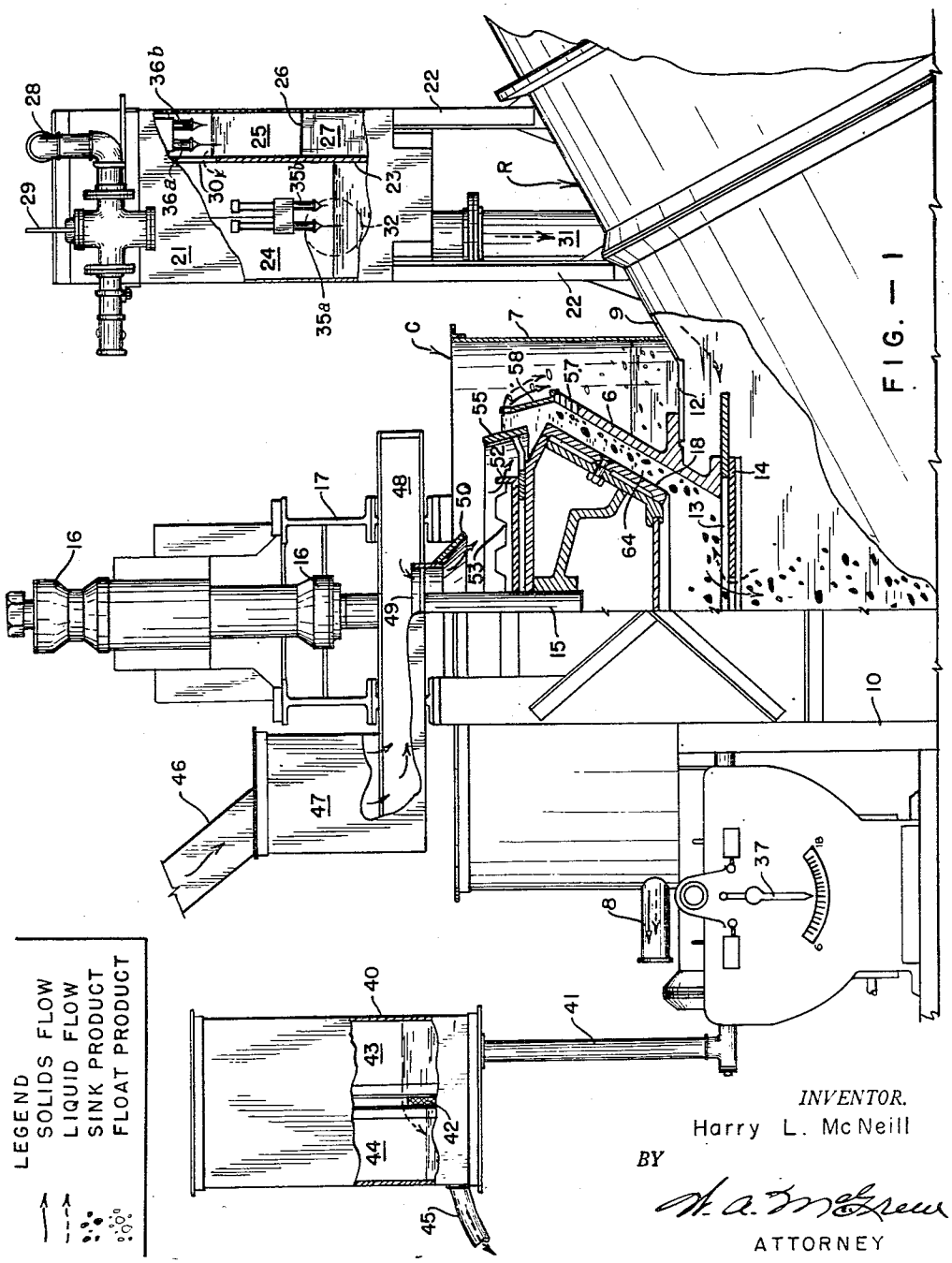


FIG. — 1

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ORE CONCENTRATION AND APPARATUS THEREFOR

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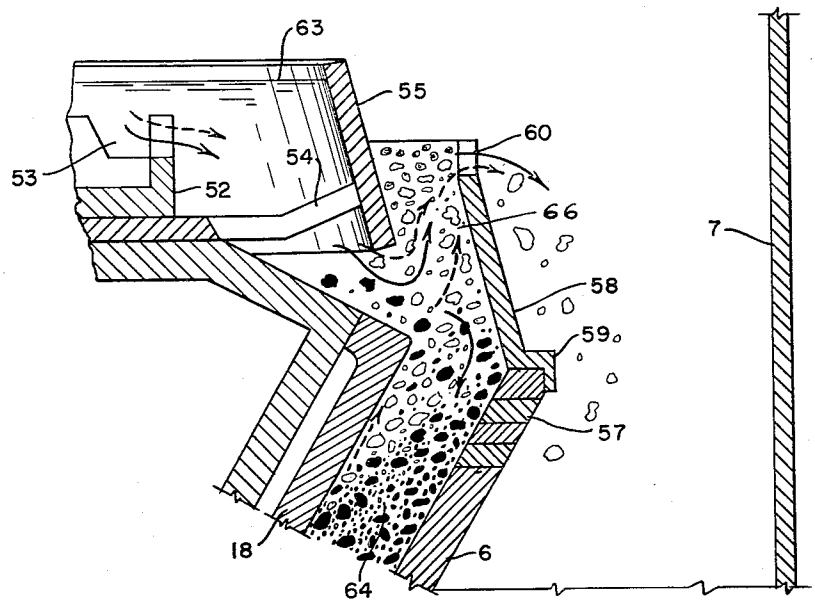


FIG. — 2

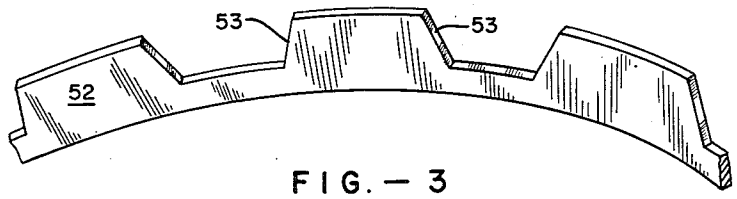


FIG. — 3

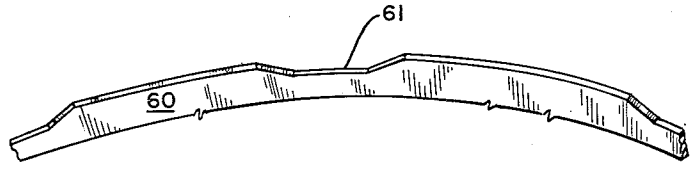


FIG. — 4

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2,777,577

ORE CONCENTRATION AND APPARATUS THEREFOR

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Application March 12, 1951, Serial No. 215,077

12 Claims. (Cl. 209—159)

This invention relates to the art of ore concentration and more particularly relates to ore concentrators of the type in which a sink and float separation is performed on a bed of the ore or other material under treatment which serves as the media of the separation. This application is a continuation-in-part of my copending application Serial No. 630,465, filed November 23, 1945, for Method and Means for Selective Media Separation, now Patent No. 2,552,378.

Commercial machines of this type are now being made in a size providing 15 feet of peripheral overflow from a conical tank structure. In order to satisfy the requirements for media formation and clean sink and float products, the overflow weir is located at an elevation above the top of the impeller. The impeller at its top is flat and has an inclined portion connecting the flat top with its conical sidewalls, and the point of interconnection of these two conical surfaces is substantially below the overflow level. Because of this relationship a tank having its sides formed as a continuous cone extending to the approximate elevation of the top surface of the impeller will form a zone of substantial width through which the float product passes to the overflow and which tends to pack and become static adjacent the peripheral wall due to its remoteness from the impeller.

As a consequence, pulp fed by gravity onto the top surface of the impeller at a central point receives additional impelling movement by the centrifugal influence of the impeller, and tends to ride across the static body of float material and discharge directly over the overflow. In this way some of the sink product may be supported by the packed float product and discharged with the float product, thereby impeding the efficiency of the separation.

In the past it has been customary to provide an annular weir on top of the impeller to get a more uniform feed distribution. In some treatments the ore being treated will contain all sizes up to 2 inch. While the 2 inch sizes will remain in suspension if suitably agitated, it is difficult to effect their discharge over such a weir, since they must be elevated above the level of the water to pass across the weir, unless some other prvoision is made for their escape.

Operating experience has shown that it is highly important to fill the voids between the coarse particles sinking through the selective media in the lower annulus. If these voids are not filled, the solids become too tightly compacted, causing excessive wear on the impeller liners. Where iron ore is treated, the feed to a given machine is often a product of another treatment containing substantially no fines, and a separation which normally would be made with 6–8 amps. indicated on the impeller motor then requires 15–20 amps.

Also, where the values are preponderantly in the fine sizes, there is danger of losing them in the tailings unless the operation permits them to descend into and through the lower annulus to pass from the treatment

with the concentrate discharge. The control is in the upward velocity of backwash water through the voids in the lower annulus, and a velocity that is correct for filling these voids with fine iron for one ore may be entirely wrong for another.

In general, low velocities are used for ores containing large quantities of fine iron and the velocity will be increased as the fines in the feed diminish. This change decreases the settling rates of the fines and holds them in the annulus longer, where they lubricate the coarse particles and create a mobile mixture.

As an illustration of the importance of the fluidity control, on one very harsh ore that had had the fines removed in another plant without being beneficiated to commercial grade, the ampere reading on the impeller motor was 12 amps. with an indicated backwash flow of 80 gallons per minute. The one and two inch pieces of silica near the overflow were locked together so closely that it was dangerous to put fingers into the upper annulus.

The indicated backwash flow was then increased to 200 G. P. M. and shortly cut back to 160 G. P. M., whereupon the ammeter reading dropped to 6 amps. and the material at the top of the treatment zone became mobile and loose to the touch, with the 2 inch pieces of silica floating off easily. (Note: the ammeter reading with water in the machine but no ore is about 4 amps. and with the machine completely empty it is 4.4 amps., indicating that the water lends buoyancy to the impeller. Impeller speed on these readings was about 50 R. P. M.)

Originally, the bearings in the drag section and the sink product control gate were water lubricated and fed from a head tank supplying the float valve control of the backwash flow. This was a low pressure supply and it was found that wear was reduced when these units were fed from a high pressure line. However, this increased the total flow materially, providing excess backwash rising through the annulus.

As shown above, too much backwash causes loss of fine iron in the tailings and an overflow weir has been provided in the present invention to conduct excess water to tailings. Adjustment of the weir up or down provides the right velocity in the voids for a given ore. As a result, machines formerly utilizing 20″–30″ of superelevation now may operate with a superelevation of 12″ to 18″ and increased recovery of fine iron.

Accordingly, it is an object of my invention to provide a simple, efficient and economical method of feed introduction and overflow control in ore concentrating processes utilizing sink and float separations in media formed from the material under treatment by centrifugal influence.

Another object of the invention is to provide a simple, durable and efficient feed distributing means for rotary concentrators.

A further object of the invention is to provide simple, durable and efficient means for controlling the overflow of rotary concentrators.

Still another object of the invention is to provide a hydraulic control for rotary concentrators which will insure proper fluidity of the material under treatment without creation of an excessive volume of overflow material.

Other objects reside in novel details of construction and novel combinations and arrangements of parts, all of which will be fully described in the course of the following description.

The present invention provides an annular feed distributor into which the feed falls by gravity. The distributor is provided at intervals about its circumferential extent with slots or recesses of substantial width and depth permitting discharge of a portion of the entering

feed at an elevation substantially below the top surface of the distributor. Provision is also made for a weir structure at the top of a tank of progressively diminishing diameter in an upwardly direction so that float material passing to the overflow is maintained in close vertical proximity to the impeller to be subjected to its agitative influence. Also, by measured control of the volume and velocity of water or other suspension media introduced in counterflow to the sink product travel, sufficient fluidity can be maintained within the bed of media effecting the sink and float separation to insure efficient separation without disturbing the efficiency of the float product discharge.

The practice of the present invention will be best understood by reference to the accompanying drawings. In the drawings, in the several views of which like parts have been designated similarly,

Fig. 1 is a fragmentary side elevation of a concentrator embodying features of the present invention, partially broken away to show the arrangement of interior parts in section;

Fig. 2 is an enlarged fragmentary section of the overflow weir and feed distributor portions of the concentrator shown in Fig. 1;

Fig. 3 is a fragmentary perspective view of a portion of the feed distributor structure shown in Fig. 2; and

Fig. 4 is a fragmentary perspective view of a portion of the overflow weir shown in Fig. 2.

The drawings illustrate a preferred embodiment of my invention, and as shown in Fig. 1 the ore concentrator comprises a concentrating unit C and a raking unit R. The concentrator C has a conical tank 6 substantially enclosed within an overflow box 7 having a discharge outlet 8 at its lower end. The overflow box is supported on an inclined top wall 9 of the raking unit and by suitable supporting structure 10. An apertured bottom 12 of the overflow box provides a support for tank 6 which has an open bottom 13 and a gate mechanism 14 selectively controlling the bottom discharge from tank 6 thru said opening 13. A rotary shaft 15 is journaled in bearings 16 supported from superstructure 17 mounted on the top of tank 6. This shaft carries at its lower end a rotary impeller 18, the details of which will be set forth in the following description. Shaft 15 is driven by a suitable motor and transmission (not shown) as disclosed in my copending application Serial No. 630,465, now Patent No. 2,552,378. A preferred embodiment will have the shaft mounted for lengthwise adjustment to vary the position of impeller 18 relative to tank 6.

The features of the raking unit are identical with those described in my application Serial No. 630,465, now Patent No. 2,552,378, and since they comprise no part of the present invention, a detailed description of same appears unnecessary. The sink product discharge through gate 14 falls to the bottom of raking unit R where it is contacted by the rakes of a raking mechanism and elevated along the inclined bottom of raking unit R to an elevated point of discharge.

A concentrator of this type requires a close control of water introduction in order to obtain optimum separation. Some water is introduced between the superposed plates of gate mechanism 14 to keep the sliding surfaces free from gritty deposits, and in the usual operation water so introduced will move upwardly in tank 6 and eventually discharge at the top of said tank. The quantity of water so introduced is usually insufficient to satisfy operating requirements, and to this end a control unit 21 is mounted on and operatively connected with the interior of raking unit R. This unit comprises a box-like structure mounted on suitable supports 22 and having its interior divided by an upright partition 23 into two compartments 24 and 25. Another partition 26 is disposed at right angles to partition 23 and has its bottom terminating at a substantial distance above the bottom of the box-like structure. This serves to divide the interior of compartment 25 into an inlet space (not shown) and an overflow space 27.

The features of the probes unit are identical with those described in my application, Serial No. 630,465, now Patent No. 2,552,378, and since they comprise no part of the present invention, a detailed description of the same appears unnecessary.

Water feed to the unit is introduced through an inlet pipe 28 under control of a float valve mechanism 29, and the discharge of the unit is through a conduit 31. Water from the supply line 28 passes into compartment 25 at a rate determined by the setting of the float valve mechanism 29 and then flows under the partition 26 into overflow space 27 where it passes through a slot weir 30 in partition 23 and falls into compartment 24 from which it discharges into conduit 31. The ball float 32 (shown in dotted line to permit illustration of the probe position) of float valve mechanism 29 is mounted for adjustment to different vertical positions to determine the valve setting.

Initially the float valve is set to maintain a predetermined liquid level. Variations in the gate control positions are effected by a pair of downstream probes 35*a* and 35*b* located in compartment 24 and a second pair of upstream probes 36*a* and 36*b* located in overflow space 27. In operation, whenever a drop in level exposes both of the probes 35*a* and 35*b*, a motor (not shown) controlling actuation of gate mechanism 14 slightly closes the opening at outlet 13 to reestablish the superelevation in compartment 24. If the level continues to go down at a rate so fast it will not be stopped by such intermittent gate closing, as when a feed shutdown occurs, then the float goes down with it and causes the flow of water over weir 30 to rise rapidly until the uppermost probe 36*b* is wetted. This probe causes the control motor to close the gate opening until stopped by a limit switch 37. At this point the water level will rise in chamber 24 and return the gate to the control of downstream probes 35*a* and 35*b*.

As the feed comes on, the density builds up in tank 6 causing a level rise in chamber 24 to a point where both downstream probes 35*a* and 35*b* become wet, which starts an intermittent gate opening action by the limit switch control 37. If the intermittent opening is not fast enough the water level will rise until the float valve is almost closed, at which time both upstream probes 36*a* and 36*b* become dry. This condition causes the control motor to open the gate continuously until the water level at the downstream probes has covered probe 35*a*, leaving probe 35*b* dry. This condition automatically brings the downstream probes into running control and leaves the upstream probes in a condition in which probe 36*a* is wet and probe 36*b* is dry.

Since the creation of a considerable superelevation in raking unit R causes a forceful flow of water into tank 6 through opening 13, it is desirable to have some means for diminishing such flow. To this end I have provided a discharge control unit 40 connected by a suitable conduit member 41 with the interior of raking unit R. The interior of control unit 40 is divided by slat weir partition 42 into an intake chamber 43 and a discharge chamber 44. A suitable outlet 45 is provided for chamber 44. By changing the elevation of weir 42 it it possible to selectively increase or decrease the volume and velocity of water delivered into tank 6 through opening 13. The discharge control unit 40 provides a constant head overflow unit, which limits the pressure of the water delivered from the rake unit R. The pressure and consequently the volume and velocity, of the water delivered into tank 6 is therefore, limited to the head determined by the overflow weir 42 of the control unit. The unit is in effect a variable height standpipe overflow.

Feed to the concentrator is delivered through a chute 46 into a feed box 47 where water may be introduced

to provide the desired pulp ratio, and suitable baffling is provided in feed box 47 to interrupt the gravitational fall of the material and to spread same as it discharges into a lower compartment 48. A feed well 49 is mounted centrally of compartment 48 with its top surface at a substantial distance above the bottom of compartment 48. This arrangement insures an even distribution of material throughout the entire area of the compartment and offsets any tendency toward the channeling movement of material into and through the well. The well member terminates in an outwardly flaring bottom portion 50. An annular feed distributor 52 is mounted on the top surface of impeller 18 in substantially concentric relation to feed well 49, and being of substantially greater diameter than the feed well receives all the discharge therethrough.

Since the distributor 52 is mounted on and rotates with impeller 18, the oversized particles in the entering feed which remain too far submerged to overflow the top surface of the distributor will ultimately move in alinement with one of a series of channels or recesses 53 providing a lower overflow level and will be carried out of the distributor in the rush of material through such recess. After passing from the distributor, the discharging pulp tends to travel in a substantially horizontal direction, but as will be best understood by reference to Fig. 2, horizontal travel is diverted by an annular or frustro-conical baffle 55 supported by a spider member 54 for rotation with impeller 18. The lower edge of baffle 55 is substantially submerged while its top edge is located well above the liquid level 63 within the baffle enclosure. For example, in the commercial machines the baffle is submerged to a depth of 1½ inches. Therefore, even when a substantial volume of material is overflowing distributor 52, the only escape for particles past baffle 55 is by diving under its lower surface. In this way, the particles are thoroughly wetted and brought within the sphere of influence of the impeller so that sink product is moved directly to the outside of the annular treatment zone 64 between the impeller and tank wall, while float product is buoyed upwardly on the float material resting on the body of selective media in the annular zone, which float material is maintained in a free and loose condition in its passage to the overflow.

This point of overflow in preferred practice may be selectively varied and to this end I provide a series of weir rings 57 on the upper wall of tank 6, the topmost of which provides a seat for the flanged bottom 59 of an annular weir overflow member 58, the top surface of which is formed as an overflow lip 60, the details of which have been shown in Fig. 4. The lip member 60 is provided at intervals with a series of channels or recesses 61 which permit the outflow of large sizes in the float product which would not readily rise across the top surface of the overflow lip. By reason of this arrangement any static condition of the pulp, and particularly the float product, is eliminated. Sink product constituents of the incoming feed are assured of ample sorting to insure following their natural settling tendencies on introduction into annular zone 64, and this material, even in fine sizes, will readily penetrate the upcast flow of float product along the conical surface of the impeller.

With this understanding of the arrangement of parts in the concentrator, reference will be made to a typical operation. For example, an iron ore in size ranges up to 2 inches constitutes the material under treatment. In the initial operation, limit switch 37 is set to provide a substantial closing of gate mechanism 14. Liquid is introduced through the supply line 28 and control unit 21 to fill the raking unit R to approximately the level indicated in compartment 24 of the unit, as shown in Fig. 1. At the same time weir 42 is positioned to provide a desired superelevation for delivering liquid into tank 6, and feed is introduced through chute 46 and feed box 47 to supply tank 6. With impeller 18 rotating, the feed delivered through feed well 49 descends into distributor 52, is discharged thereby into the enclosure formed by baffle 55 and is thus caused to descend into the annular zone 64 between the impeller and tank wall 6. The limited underflow discharge causes the solids to form a bed of media in the annular zone 64 which comprises a mixture of float and sink product with a specific gravity intermediate the specific gravities of the float and sink products.

Once the media is formed, the resulting density condition creates additional superelevation of the liquid in control unit 21 with the result that probes 36*a* and 36*b* both become wet and thus signal the control mechanism for opening of the gate mechanism 14. When the gate opens, sink product comprising iron concentrate travels downwardly through zone 64 in approximately the pattern indicated in Fig. 2, and thence through the discharge opening into the raking unit R where it is moved upwardly along the inclined bottom by the action of the rakes and eventually discharges from the concentrator.

The float material comprising waste rock which is unable to penetrate the media bed rises through the space 66 between baffle 55 and the annular overflow weir 58 to overflow said weir into the bottom of overflow box 7 from which it discharges through the outlet 8. This operation continues so long as feed is supplied with control unit 21 providing intermitent adjustments of the gate position in response to the indicated changes in feed as previously described.

The relation of water input through supply line 28 with the discharge rate established by the setting of weir 42, insures supply of ample water upwardly through the opening 13 in the bottom of tank 6, and thence into the annular zone 64 to insure ample fluidity of the material without excessive discharge of water at overflow 60. The action of feed distributor 52 and baffle 55 insures proper distribution of the entering feed and sufficient submergence of the sink product content of such feed to insure a clean separation of the sink and float product under the optimum separating conditions maintained in zone 66. In this connection it will be understood that the speed of rotation of the impeller and the gap setting between the impeller and the sides of tank 6 and also as between the impeller and overflow weir 58 is arranged for optimum separation of a given ore.

The control of feed distribution to the concentrator unit, coupled with the complete submergence of the feed as it is delivered into the annular zone and onto the bed of media therein and the close regulation of water input into the separation zone followed by controlled discharge of the float product and water from said zone, provide a clean float product discharge. Likewise, the operation of the impeller at a speed predetermined to provide optimum separation for a given ore at the gap provided by the spacing of the impeller from the tank insures a highly efficient sink and float separation on the bed of media maintained within zone 64. The control of the sink product discharge through the proper gate setting and in conjunction with the hydraulic control aforementioned insures a clean sink product discharge from the concentrator unit. In the case of an iron ore of the type taken for this treatment, it is possible to obtain a sink product discharge of the iron content in substantially all size ranges, while at the same time substantially eliminating any discharge of float product slimes with the sink product.

As shown in Figs. 1 and 2, the baffle 55 has a second function of cooperating with the overflow member 58 in defining the upper annulus or float product selective zone immediately above the lower annulus or primary treatment zone 64. Through this arrangement the float product rising from the bed of media in zone 64 is kept loose and in a highly selective condition.

In the early stages of the development of this type

of selective media separation, the principle effort was directed toward the creation of a compacted body of media in the annular zone between the impeller and tank walls, which was of a density intermediate the sink and float product. Consequently, no particular effort was directed toward a control of float product and maintenance of a highly selective condition near the overflow.

The need for such control is particularly evident in separating the KCl and NaCl constituents of sylvinite ores suspended in a saturated brine of the ores. Due to the slight difference in gravity between these compositions there is a tendency for the superelevation to fluctuate, causing surging in the annulus. With the overflow discharge control unit 40 set so that only the surges go over the weir 42 and not upwardly through the lower annulus 64, a cleaner separation is obtained in continuous operation.

In this connection, it will be understood that in the practice of the present invention the coarse fraction of the float product is maintained at or near the surface in the upper annulus 66, thereby permitting the sink product, irrespective of size, to sink readily into the bed of media in zone 64 after it has been forced under the lower edge of baffle 55.

While the features of the present invention have been described with particular reference to iron ore treatments, it will be understood that a wide variety of materials may be treated efficaciously in this manner. In particular, coal-slate mixtures and sylvinite ore are amenable to the treatment. The separations thus far described have involved differences in specific gravity as between constituents of the material under treatment. However, as pointed out in my copending application Serial No. 630,465, now U. S. Patent No. 2,552,378, size classification treatments also may be performed in the apparatus described herein and the features of novelty previously described will contribute to the efficiency of any such operation.

What is claimed is:

1. In a rotary concentrator of the type having an annular treatment zone within a space defined by a massive rotary impeller, a tank wall disposed substantially parallel to the sides of said impeller, and having an overflow for float product adjacent the top of said annular zone, the improvement which comprises an annular feed distributor mounted on and substantially concentric with the top surface of the impeller for conjoint rotation therewith and adapted to receive pulp fed to the concentrator, said distributor having a series of elongated channel recesses in its top surface disposed at intervals throughout its circumferential extent for the discharge of maximum size submerged solids in the feed at a point below the effective overflow level of the distributor.

2. In a rotary concentrator of the type having an annular treatment zone within a space defined by a massive rotary impeller, a tank wall disposed substantially parallel to the sides of said impeller, and having an overflow for float product adjacent the top of said annular zone, the improvement which comprises an annular weir member mounted on the top surface of said tank wall and determining the overflow level of said tank, said weir having means for engagement with said top surface, said weir member having a series of elongated channel recesses in its upper surface disposed at intervals throughout its circumferential extent for the discharge of oversize particles of the float product at a point below the effective overflow level of the tank.

3. In the ore concentration art in which a rotary impeller is mounted with its sides substantially parallel to the side of a tank for pulp in which it operates and over which float product is removed by overflow, the improvement which comprises an annular feed distributor mounted at the top of the impeller in at least a partially submerged position adapted to receive pulp fed to the concentrator, and an annular baffle supported from the impeller exteriorly of the distributor in the horizontal plane of said distributor with its lower edge substantially submerged and spaced apart from said impeller and its upper edge above the upper edge of the distributor.

4. In the ore concentration art in which a rotary conical impeller is mounted with its sides substantially parallel to the sides of a tank for pulp in which it operates, the improvement which comprises an annular overflow weir seated on the top surface of the tank at approximately the upper limit of the conical surface of the impeller and having its inner surface substantially upright and inclining inwardly so as to provide a narrowing selective zone for float product ascending to a point of overflow at the upper edge of said weir.

5. In the ore concentration art in which a rotary impeller is mounted with its sides substantially parallel to the side of a tank for pulp in which it operates and over which float product is removed by overflow, the improvement which comprises an annular feed distributor mounted at the top of the impeller in at least a partially submerged position adapted to receive pulp fed to the concentrator, and an annular baffle supported and spaced from the impeller exteriorly of the distributor in the horizontal plane of said distributor with its lower edge substantially submerged and its upper edge positioned substantially above the overflow level of said tank.

6. In the ore concentration art in which an ore pulp is continuously fed into an annular zone of centrifugal movement between a rotor and a stator, is subjected to the action of a sorting column comprising an upcast flow of float product inwardly of said zone and a downcast travel of sink product exteriorly of said upcast flow, and float product is continuously discharged by overflow at the top of said zone while sink product is discharged through a bottom structure providing a support for the material in said zone, the improvement which comprises feeding the pulp internally of said annular zone below and adjacent the overflow level of said zone for centrifugal discharge thereby, and causing sink particles of the feed to submerge substantially below the overflow level in the centrifugal flow directed in penetrating relation to said upcast and downcast flows.

7. In the ore concentration art in which an ore pulp is continuously fed into an annular zone of centrifugal movement between a rotor and a stator, is subjected to the action of a sorting column comprising an upcast flow of float product and a downcast travel of sink product, and float product is continuously discharged by overflow at the top of said zone while sink product is discharged through a bottom structure providing a support for material in said zone, the improvement which comprises feeding pulp internally of said annular zone below and adjacent the top of said zone for centrifugal discharge thereby at the overflow level of said zone, and causing sink particles of the feed to submerge substantially below the overflow level in a flow directed in penetrating relation through said inner upcast flow and into the downcast flow.

8. In the ore concentration art in which a rotary conical impeller is mounted with its sides substantially parallel to the sides of a tank for pulp in which it operates, the improvement which comprises an annular overflow weir seated on the top surface of the tank at approximately the upper limit of the conical surface of the impeller and having its inner surface inclining inwardly in an upward direction to a point adjacent a vertical surface conforming to the periphery of the impeller so as to provide a selective zone for float product ascending to narrowing point of overflow at the upper edge of said weir.

9. In the ore concentration art in which a rotary impeller is mounted with its sides substantially parallel to the sides of a tank for pulp in which it operates, the improvement which comprises an annular overflow weir mounted on the top surface of the tank with its overflow level above but adjacent to the top surface of the im-

peller, and an annular baffle mounted on and spaced from the impeller with its top surface above the overflow level and its bottom surface submerged so as to define with the overflow weir an annular treatment zone in the upper portion of said tank.

10. In the ore concentration art in which a rotary conical impeller is mounted with its sides substantially parallel to the sides of a tank for pulp in which it operates, the improvement which comprises an annular overflow weir mounted on the top surface of the tank with its overflow level above but adjacent to the top surface of the impeller, an annular baffle mounted on and spaced from the impeller with its top surface above the overflow level and its bottom surface submerged so as to define with the overflow weir an annular treatment zone in the upper portion of said tank, said tank walls and impeller defining a lower annulus beneath said treatment zone, and the inner surface of said overflow weir being disposed in converging relation to the tank walls defining said lower annulus.

11. In the ore concentration art in which a rotary impeller is mounted with its sides substantially parallel to the sides of a tank for pulp in which it operates so as to form a lower annular treatment zone for material fed to the tank, the improvement which comprises an annular overflow weir mounted on the top surface of the tank with its overflow level above but adjacent to the top surface of the impeller, and an annular baffle mounted on and spaced from the impeller in spaced relation to said annular weir with its top surface above the overflow level and its bottom surface submerged so as to define with the overflow weir an upper annular treatment zone in direct hydraulic communication with said lower annular zone.

12. In ore treating apparatus, a tank including an upright circular wall portion, a bottom provided with a central sink product outlet, and an upper float product overflow weir, a rotary impeller having an upright surface defining with said wall portion a relatively narrow, annular zone and defining with said bottom a substantially cylindrical zone for a crowding discharge movement of sink product to said bottom outlet, means for introducing material to be treated onto the top surface of the impeller as feed to the annular zone, means adjustable during rotation of the impeller for varying the discharge through said bottom outlet, means for holding a body of liquid outside said bottom outlet under sufficient head to circulate upwardly through said outlet, and regulating means for varying the liquid flow through said outlet in accordance with indicated changes in the fluidity of the material in said annular zone.

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